

LAW OFFICES

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Box PATENT APPLICATION

The Commissioner of Patents and Trademarks  
Washington, D. C. 20231

Sir:

Enclosed herewith for filing is the patent application of inventor(s), John R. Moser, Jr., for "REDUCED ENERGY BINDER FOR ENERGETIC COMPOSITIONS" together with the following:

- (1) The Declaration, Power of Attorney and Petition executed by the inventor(s);
- (2) An assignment of the invention to Alliant Techsystems Inc., executed by the inventor(s); and
- (3) The filing and recording fees thereon are calculated as follows:

Basic Fee . . . . .	\$ 790.00
Total number of claims in excess of 20, times \$22.00 . . . . .	\$ 88.00
Number of independent claims, minus 3, times \$82.00 . . . . .	\$ 164.00
Surcharge fee (\$270.00) for filing of multiple dependent claim(s) . . .	\$ 0
Fee for recording assignment . . . .	\$ <u>40.00</u>
Total Filing and Recording Fee . . .	\$ 1082.00

A check in the amount of \$1082.00 is enclosed to cover the filing and recording fees.

The Commissioner is authorized to charge any fees or refund any overpayment under 37 CFR 1.16 and 1.17 which may be required by this paper to Deposit Account No. 08-1265.

Yours very truly,

HAUGEN AND NIKOLAI, P.A.



C. G. Mersereau

CGM/bld  
Enclosures

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**REDUCED ENERGY BINDER FOR ENERGETIC COMPOSITIONS****BACKGROUND OF THE INVENTION****I. Field of the Invention**

The present invention relates generally to energetic compositions or formulations, particularly solid high energy compositions including propellants, explosives, gas generators and the like. More particularly, the invention focuses on improvements for reducing hazards sensitivity and product cost in propellant compositions.

10 The hazards sensitivity is reduced by substantially reducing the required relative amount of shock sensitive energetic plasticizers, particularly nitrate esters, such as nitroglycerin (NG), by replacing the conventional binder polymer and part of the plasticizer with a binder polymer  
15 more easily plasticized.

One important aspect of the invention focuses on the discovery that amounts of relatively high molecular weight polyester prepolymers, particularly polyester polyols, can be combined successfully with surprisingly low levels of  
20 energetic plasticizers (particularly nitrate esters) in energetic compositions that are relatively low cost and characterized by comparable or superior mechanical properties. A preferred binder polymer is an isocyanate-cured, high molecular weight polyester diol poly(1,4-  
25 butanediol adipate) or poly(tetramethylene adipate) (PTMA). The invention also enables improved formulae in which high cost, relatively sensitive, high energy, energy adjustment compounds, such as cyclic nitramines of fine particle size, including cyclotrimethylene trinitramine (RDX) or  
30 cyclotetramethylene tetranitramine (commonly referred to as HMX) can be, if desired, partially or completely replaced by aluminum and ammonium perchlorate (AP) oxidizer and/or other combinations of particulate solids. Such cyclic nitramines of fine particle size are typically used to  
35 increase the energetic performance and to improve the mechanical properties of the composition.

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## II. Related Art

Solid, high energy compositions such as rocket propellants, gas generators, explosives, and the like, generally contain particulate solids in the form of oxidizers, fuels, burning rate modifiers, solid explosives, etc., dispersed in elastomeric binders. The elastomeric binders themselves may contain inert polymer materials, but these compositions may also contain high energy, hazards sensitive plasticizers, such as nitrate esters. These plasticizing materials are known to enhance the mechanical properties as well as the energy output of the overall composition. The typical ratio, by weight of plasticizer to total polymer (including prepolymers, crosslinkers and curatives) in binder materials (commonly known as the Pl:Po ratio) is about 2-4, i.e., 2 to 4 parts of energetic plasticizer to one part of polymer in the binder.

Recently, more stringent requirements imposed for lower hazards sensitivity have led to an increased demand for lower energy, but not entirely inert, binders which have become known as reduced energy or intermediate energy binders. The general approach to developing these binders has been to replace or dilute very high energy plasticizers with lower energy plasticizers while holding the Pl:Po ratio substantially constant at about 2-4.

An alternative approach to this problem which seemed logical was to simply dilute the high energy plasticizers with additional binder polymer material to reduce the overall binder energy as this would provide a more dense polymeric network which, in turn, would be expected to be a great deal tougher and more resistant to physical damage, another critical consideration for reducing hazards sensitivity. It was found, however, that at the resultant lower Pl:Po ratios, the lower fraction of plasticizer was insufficient to properly plasticize the binder polymer and this resulted in unsatisfactory mechanical properties, especially with regard to low elongation. Thus, there has remained a need to solve the problem of fully plasticizing the binder polymer at lower Pl:Po ratios to reduce hazards

sensitivity in a manner which preserves good mechanical properties or even enables improvements in mechanical properties.

Crosslinked binders disclosed by Baczuk et al (U.S. Patent 4,386,978) include urethane rubber materials that include certain polyester diols which contain both aliphatic and aromatic ester functions. These are combined with a poly-functional isocyanate having an NCO (isocyanate) functionality of at least 3. Energetic plasticizers are not reduced, however.

Godsey et al (U.S. Patent 5,468,311) discloses a composition having a binder system that includes polyols which may be polyesters or polyethers having a molecular weight from about 400 to about 4,000 and hydroxyl functionalities from about 2.0 to about 2.8. The preferred polyol is polyethylene glycol adipate. The preferred molecular weight range is from about 2,000 to about 3,000. A further patent to Godsey (U.S. Patent 4,298,411) depicts a propellant system that includes a pre-polymer of a hydroxy-terminated polyester and an isocyanate used in very small amounts as a crosslinking agent.

In U. S. Patent 4,775,432 to Kolonko et al, it has further been proposed to use relatively high molecular weight poly(caprolactone) polymers in propellant binders. Those formulae, however, require a ratio of plasticizer to binder that is at least 2.0:1 and preferably at least 2.5:1.

Whereas each of the above references addresses certain previous drawbacks in the art, none predict a low cost, reduced hazards energetic formulation with desired mechanical properties.

Accordingly, it is a primary object of this invention to provide an improved binder system for energetic compositions which maintains excellent mechanical properties, together with reduced hazards sensitivity.

A further object of the invention is to replace an amount of energetic plasticizers in binders for energetic

compositions with binder polymers without sacrificing good mechanical properties.

It is another object of this invention to provide an improved binder system for high energy compositions using  
5 high molecular weight polyester prepolymers combined with a relatively low level of energetic plasticizer.

Yet another object of this invention is to provide lower cost energetic compositions of reduced hazards sensitivity and desirable mechanical characteristics.

10 A still further object of this invention is to provide an improved binder system for high energy compositions utilizing isocyanate crosslinked or cured, relatively high molecular weight PTMA pre-polymer as the binder polymer.

Yet still another object of the invention is to  
15 provide lower cost energetic materials by replacing part or all of the RDX or HMX fraction with a suitable solid material combination such as AP and aluminum.

Other objects and advantages will become apparent to those skilled in the art upon becoming familiar with the  
20 descriptions and accounts contained herein together with the appended claims.

#### SUMMARY OF THE INVENTION

The present invention overcomes many drawbacks in prior energetic compositions by the provision of improved  
25 reduced energy binder compositions for solid, high energy formulations including propellants, explosives, gas generators and related materials, together with formulations using these binders. The binders of the invention are particularly advantageous because they are  
30 relatively low cost and exhibit improved hazards properties relative to similar, higher energy binders. In addition, the binders promote excellent mechanical properties which allow additional composition variation leeway which, in turn, can be used to reduce cost and hazards sensitivity  
35 still further. The excellent mechanical properties survive in the formulations even without the reinforcement of fine particle size nitramines such as HMX and RDX.

The binders are useful with any commonly used solid energetic species and successfully employ binder polymer materials to replace at least part of the energetic plasticizers thereby reducing the levels of energetic plasticizers, particularly nitrate esters, required in the binder. The binder system of the invention succeeds mechanically at levels of energetic plasticizers that are quite low.

The invention accomplishes the foregoing advantages by providing unique binder compositions that employ a cured high molecular weight polyester matrix, particularly polyester polyols which readily undergo crosslinking curing through active hydroxyl group sites using polyisocyanates in combinations with relatively low levels of energetic plasticizers. The preferred embodiment uses high molecular weight poly(tetramethylene adipate) or PTMA with NG, but other energetic plasticizers such as *n*-butyl-2-nitratoethyl nitramine (BuNENA), trimethylolethane trinitrate (TMETN), triethyleneglycol dinitrate (TEGDN), butanetriol trinitrate (BTTN) and other materials also function effectively.

The polyester prepolymer materials of the invention are compounds that are readily plasticized by energetic plasticizers including nitrate ester compounds such that the relative level of high energy plasticizer can be reduced significantly. The formulas make use of material that is sufficiently plasticized at low Pl:Po ratios of about 1.0 such that lower hazards sensitivity advantages associated with the higher relative polymer levels can be taken. It has been found, for example, that PTMA of a rather high molecular weight (MW ~ 6,000 in which the MW is a number average molecular weight) works extremely well. When used with NG at an approximate ratio of 1:1, or even slightly less, the polymer is sufficiently plasticized to enable excellent or superior mechanical properties to be realized.

While the detailed description focuses on the use of PTMA, it is believed that other high molecular weight

polyester polyol materials having sufficient reactive hydroxyl group sites to react with a crosslinking agent, particularly a polyisocyanate, to form a cured polymer matrix may behave similarly. Thus, linear and moderately  
5 branched polyester polyols derived from aliphatic and/or aromatic starting materials, or from polymerizable lactones or mixtures thereof of sufficient molecular weight may function in a similar manner. Examples of other such compounds include poly(1,4-butanediol azelate),  
10 poly(diethyleneglycol adipate), poly(1,6-hexanediol adipate), poly(1,3-butanediol adipate), etc.

The present invention also provides reduced or intermediate energy binder propellant systems of reduced cost and reduced hazards sensitivity which maintain  
15 superior mechanical properties. Some formulas reduce both cost and hazards sensitivity by reducing or eliminating RDX or HMX and further reduce hazards sensitivity by utilizing novel, reduced energy binders. In this manner, it has been found, for example, that some or all of the high priced  
20 components RDX or HMX can be replaced by less expensive AP oxidizer and aluminum or other solids combinations.

In one example, a 75% solids propellant was prepared which utilized 53% unground (200 $\mu$ ) ammonium perchlorate and 22% aluminum (30 $\mu$ ). That formula also contained 11.3% PTMA  
25 of MW approximately 6,200 and 12.19% NG. The propellant gave outstanding mechanical properties and less than 69 cards in NOL card gap testing.

According to the invention, it has also been found that a combination of plasticizers may be used in such  
30 formulas including amounts of inert materials to provide further flexibility in formulating useful mixes. An example of such an inert plasticizer is triacetin (TA) or triacetyl glycerine. The use of amounts of inert plasticizer allows a further reduction in the required  
35 amount of energetic plasticizer. The percentage of inert plasticizer used may vary greatly in the binder, which itself may vary greatly in the mix. One successful formula

used about 2.5% TA and another about 1.4% TA.

As a general comment with respect to many of the ingredients used in the several exemplary formulae disclosed herein, the following is a partial list of ingredient functions in the energetic compositions:

- NC - crosslinker
- PTMA - prepolymer
- N-100, DDI, IPDI - isocyanate curatives
- NG, TMETN, BuNENA, etc. - energetic plasticizers
- TA - inert plasticizer
- 2-NDPA, MNA - stabilizers
- AP - oxidizer, burn rate modifier
- NaNO<sub>3</sub> - oxidizer, chloride scavenger
- DCDA - burn rate suppressant
- Al - fuel
- TPB - cure catalyst

It is expected that a range of molecular weights for the PTMA binder material may be successfully used; however, it has been discovered that using molecular weights that are higher produces surprisingly superior results at low Pl:Po ratios. With PTMA, it is believed that the preferred range of molecular weights of PTMA begins above about 4,000 and preferably above 5,000, material of approximately 6,000 MW or greater is most preferred being found highly successful. The material has allowed the formulation of low-binder-energy propellant that requires no HMX or RDX and so can be made out of lower cost materials.

Another important advantageous characteristic of the binders of the invention is a relatively high electrical conductivity. This is also important with respect to reducing hazards by assisting in preventing the accumulation or buildup of large static charges in the associated energetic compositions.

#### DETAILED DESCRIPTION

The goals of the energetic formulae or compositions of the present invention are to reduce cost and reduce hazards



sensitivities (hazards class 1.3) in energetic compositions including missile propellants. The energetic compositions of the invention use a binder system that includes a high molecular weight polyester polyol (polyester prepolymer) 5 binder polymer and an energetic plasticizer. The invention is based, at least in part, on the discovery that certain higher molecular weight polyols (polyester prepolymer) binder compounds are plasticized in the cured state much more readily than expected by energetic 10 plasticizers to enable the Pl:Po to be reduced to just above 1.0 or even less. These compounds are particularly characterized by attached hydroxyl groups that provide reactive sites that react with crosslinking agents, particularly isocyanates to form the cured polymeric 15 matrix. While the examples of the detailed description particularly disclose PTMA, this is intended to be interpreted as illustrative rather than limiting and many other polyester polyol-type compounds including linear and moderately branched hydroxyl polyester compounds derived 20 from aliphatic and/or aromatic starting materials or from polymerizable lactones may work successfully. In addition, high priced, solid, energy enhancement ingredients such as nitramines including RDX and HMX can be replaced in whole or in part by solid materials such as Al and AP or possibly 25 sodium nitrate ( $\text{NaNO}_3$ ).

Thus, the improvement achieved with the present reduced-binder-energy compositions is two-fold: (1) they can be used to reduce hazards sensitivity and cost by enabling partial or total replacement of RDX, HMX, etc., 30 with AP, Al, and/or other solids and (2) they further reduce hazards sensitivity by providing binders that dramatically reduce the required relative amount of energetic plasticizer enabling replacement of some of the energetic plasticizer (NG, TMETN, BuNENA, etc.) with 35 polymer.

As indicated, poly(1,4-butanediol adipate) or poly(tetramethylene adipate) (PTMA) is the most preferred

binder polymer and it may also be identified by Chemical Abstracts Service (CAS) Registry Number 25103-87-1. In accordance with the invention, the required amount of high energy plasticizer such as energetic nitrate esters, particularly NG, can be reduced significantly while attaining as good or even superior mechanical properties. It will be understood that while detailed embodiments described herein are solid propellants typically used as rocket propellants, these are meant by way of example only and are in no way intended to limit the scope of application of the binder materials of the invention.

**EXAMPLE 1**

A baseline reduced-binder-energy propellant used a 0 cal/g (binder heat of explosion,  $\text{HeX}_b$ ) PTMA/NG binder in a 75%-solids propellant shown to give outstanding mechanical properties. That particular formula used all unground 200 $\mu$  AP. This formulation is shown in Table I. One-pint-mix properties of this formulation are shown in Table II. Such a formula is suitable for strategic missile propulsion, for example.

This formula is successful in accordance with a preferred embodiment of the invention. High molecular weight (6,000 or higher) PTMA has been found to become sufficiently plasticized at very low P1:P0 ratios (approximately 1:1).

TABLE I

Baseline reduced-binder-energy formulation			
	Ingredient	Weight %	
	RS 5 sec NC	0.06	Percent Solids 75
5	PTMA 6000	11.30	Pl:Po 0.99
	N-100	0.97	Hex <sub>6</sub> (cal/g) 0
	NG	12.19	NC/PTMA 0.005
	2-NDPA (2-nitrodiphenylamine)	0.12	NCO/OH 1.3
10	MNA (N-methyl-p-nitroaniline)	0.36	theor. I <sup>0</sup> <sub>sps</sub> (lb <sub>f</sub> s/lb <sub>m</sub> ) 260.4
	AP (200μ)	53.00	theor. ρ (g/cc) 1.84
	Al (30μ)	22.00	theor. flame T (°K) 3756
	TPB	(0.01)	

TABLE II

One-pint-mix properties of baseline reduced-binder-energy formulation (using all 200μ AP, except as noted).			
5	Tensile properties @ 2 in/min, 77°F		
	σ <sub>m</sub> (psi)	84	
	ε <sub>m</sub> (%)	244	
	ε <sub>r</sub> (%)	244	
10	E <sub>0</sub> (psi)	1610	
	120°F viscosity (kP)		
	η <sub>0.36</sub>	7	
	η <sub>0.008</sub>	12	
	120°F pot life (hr)	~27-36	
15	Ballistic properties (with 50/50 90μ/200μ AP)		
	70-g motor r <sub>1000</sub> (in/s)	0.41	
	70-g motor n	0.3	
	CIV (ft/s)	806	
	NOL card gap		
20	1 no-go at 69 cards		
	Hazards sensitivity		
		uncured	cured
25	impact (cm)	6.9	21
	friction (lb <sub>r</sub> @ ft/s)	40 @ 8	100 @ 8
	ESD (J)	0.15	0.26
	FJAI (°C)	>300	>300

The viscosity of this propellant of 7 kP/12 kP (at 0.36 s<sup>-1</sup>/0.008 s<sup>-1</sup> shear rates) indicates that it would be easily processible in full-scale mixes. The pot life of approximately 27-36 hours is similar to that of current propellants used in rocket motors requiring multiple full-scale castings.

At 2 in/min, 77°F, the baseline reduced-binder-energy propellant gave  $\sigma_m/\epsilon_m/\epsilon_r/E_0$  values of 84 psi/244%/244%/1610 psi (one-pint mix); where  $\sigma_m$  is tensile strength;  $\epsilon_m$  is elongation at maximum stress;  $\epsilon_r$  is elongation at rupture and  $E_0$  is the initial tangent modulus. These properties were tested using JANNAF Class C tensile specimens. Although the abnormally high modulus should not present problems, additional one-pint mixes were made using a diisocyanate, isophorone diisocyanate (IPDI), with N-100 to reduce modulus and achieve even higher elongation. This approach proved to be effective:  $\sigma_m/\epsilon_m/\epsilon_r/E_0$  values at 2 in/min, 77°F went to 113 psi/414%/414%/1280 psi with 80:20 (isocyanate equivalents) N-100:IPDI, and to 88 psi/455%/457%/900 psi with 60:40 N-100:IPDI.

CIV (critical impact velocity) testing, to determine material toughness, was performed on the baseline reduced-binder-energy propellant. The result was 806 ft/s (similar to Trident I C-4 propellants VRP and VTG-5A), indicating low friability.

The appearance of the burning aluminum particles (small, bright) in the microwindow bomb has indicated high combustion efficiency in the reduced-binder-energy propellant. 70-gram motors gave a burn rate at 1000 psi of 0.41 in/s which was higher than predicted by a propellant burn rate model (but this was an empirical model based on HMX-loaded propellants with lower levels of AP). The low slope of 0.3 was not unexpected at this high AP level. This propellant, with 53% AP, should be widely tailorable to adjust burn rate.

#### EXAMPLE 2

Another binder produced outstanding mechanical

properties in an 84%-solids, low hazards (-850 cal/g Hex<sub>9</sub>)  
propellant containing 55% coarse (400 $\mu$  and 200 $\mu$ ) AP and no  
bonding agents. This binder also used 6000 molecular  
weight PTMA. The primary plasticizer in this binder was  
5 BuNENA [the BuNENA was diluted slightly (~1:5) with an  
inert co-plasticizer, TA] and the Pl:Po ratio was 1.0.  
Although modulus was very high (2530 psi),  $\sigma_m$  and  $\epsilon_m$  values  
were also extremely high for a propellant with an energetic  
binder and such a high level of such coarse solids--104 psi  
10 and 174%, respectively @ 2 ipm, 77°F. Properties were  
demonstrated and verified using a one-pint mixer. This  
example is also shown in Table III and in Table IV.

This example indicates that relatively small amounts  
of a variety of energetic plasticizers probably will  
15 successfully plasticize high molecular weight PTMA  
including plasticizers such as triethyleneglycol dinitrate  
(TEGDN) and butanetriol trinitrate (BTTN) and others.

TABLE III

Reduced-binder-energy formulation with BuNENA/TA plasticizer			
	Ingredient	Weight %	
	RS 5 sec NC	0.04	Percent Solids 84
5	PTMA 6000	7.23	P1:Po 1.00
	N-100	0.62	Hex <sub>8</sub> (cal/g) -850
	BuNENA	6.47	NC/PTMA 0.005
	TA	1.41	NCO/OH 1.3
	MNA	0.23	theor. I <sup>0</sup> <sub>aps</sub> (lb <sub>f</sub> s/lb <sub>m</sub> ) 261.0
10	AP (20μ)	5	theor. ρ (g/cc) 1.85
	AP (200μ)	20	theor. flame T (°K) 3712
	AP (400μ)	35	
	Al (30μ)	22	
15	DCDA (dicyandiamide) (<10μ)	2	
	TPB	(0.01)	

TABLE IV

One-pint-mix properties of reduced-binder-energy formulation using BuNENA/TA plasticizer.

5	Tensile properties @ 2 in/min, 77°F	
	$\sigma_m$ (psi)	104
	$\epsilon_m$ (%)	174
	$\epsilon_r$ (%)	176
10	$E_0$ (psi)	2350
	120°F viscosity (kP)	
	$\eta_{0.36}$	10
	$\eta_{0.008}$	29

TABLE V

15 Reduced-binder-energy formulation with mixed NG/TA plasticizer

	Ingredient	Weight %		
	RS 5 sec NC	0.05	Percent Solids	75
	PTMA 6000	9.88	P1:Po	1.26
	N-100	0.67	Hex <sub>8</sub> (cal/g)	-100
20	DDI (dimeryl diisocyanate)	0.26	NC/PTMA	0.005
	NG	11.24	NCO/OH	1.3
	TA	2.46	theor. $I^0_{sp}$ (lb <sub>f</sub> s/lb <sub>m</sub> )	259.7
	2-NDPA	0.11	theor. $\rho$ (g/cc)	1.83
25	MNA	0.33	theor. flame T (°K)	3728
	AP (20 $\mu$ )	8		
	AP (400 $\mu$ )	45		
	Al (30 $\mu$ )	22		
	TPB	(0.01)		



TABLE VI

One-gallon-mix properties of reduced-binder-energy formulation using mixed NG/TA plasticizer.	
5	Tensile properties @ 2 in/min, 77°F
	$\sigma_m$ (psi) 79
	$\epsilon_m$ (%) 350
	$\epsilon_r$ (%) 352
10	$E_0$ (psi) 799
	120°F viscosity (kP)
	$\eta_{0.36}$ 3
	$\eta_{0.008}$ 5
	120°F pot life (hr) 48
15	Ballistic properties (one-pound motors)
	$r_{1000}$ (in/s) 0.353
	$n$ 0.29

### EXAMPLE 3

Another propellant formula which produced excellent  
 20 mechanical properties is shown in Table V and the one-gallon-mix properties are shown in Table VI. This formula uses an amount of TA along with the NG as plasticizers.

### EXAMPLE 4

The formula of this example is shown in Table VII and  
 25 illustrates a propellant formula that is plasticized with TMETN. This formulation also exhibits excellent mechanical and processing properties as shown in Table VIII.

### EXAMPLE 5

The formula and mechanical properties of this example  
 30 can be seen in Tables IX and X, respectively. In this

example, a substantial fraction of the AP oxidizer has been replaced by  $\text{NaNO}_3$ . As with the mixes of previous examples, the mechanical and processing properties were excellent. This mix was also tested for volume resistivity.

5

TABLE VII

Reduced-binder-energy formulation with TMETN plasticizer			
	Ingredient	Weight %	
	RS 5 sec NC	0.06	Percent Solids 75
	PTMA 6000	11.34	P1:Po 1.00
10	N-100	0.78	Hex <sub>B</sub> (cal/g) -260
	IPDI	0.11	NC/PTMA 0.005
	TMETN	12.32	NCO/OH 1.3
	2-NDPA	0.03	theor. $I_{sp}^0$ (lb <sub>f</sub> s/lb <sub>m</sub> ) 261.0
	MNA	0.36	theor. $\rho$ (g/cc) 1.82
15	AP (20 $\mu$ )	10	theor. flame T (°K) 3663
	AP (200 $\mu$ )	43	
	Al (30 $\mu$ )	22	
	TPB	(0.01)	

TABLE VIII

One-pint-mix properties of reduced-binder-energy formulation using TMETN plasticizer.	
5	Tensile properties @ 2 in/min, 77°F
	$\sigma_m$ (psi) 134
	$\varepsilon_m$ (%) 338
	$\varepsilon_r$ (%) 340
10	$E_0$ (psi) 1080
	120°F viscosity (kP)
	$\eta_{0.36}$ 4
	$\eta_{0.008}$ 6
	120°F pot life (hr) 50-53

TABLE IX

Reduced-binder-energy formulation with AP, Al, and $\text{NaNO}_3$ solids			
	Ingredient	Weight %	
	RS 5 sec NC	0.06	Percent Solid 74.75
5	PTMA 6000	11.42	P1:Po 0.99
	N-100	0.98	Hex <sub>8</sub> (cal/g) 0
	NG	12.31	NC/PTMA 0.005
	2-NDPA	0.12	NCO/OH 1.3
	MNA	0.36	theor. $I^0_{\text{sp}} (\text{lb}_f\text{s}/\text{lb}_m)$ 245.7
10	AP (5 $\mu$ )	13	theor. $\rho$ (g/cc) 1.89
	AP (70 $\mu$ )	17	theor. flame T ( $^{\circ}\text{K}$ ) 3732
	Al (30 $\mu$ )	23	
	$\text{NaNO}_3$ (<70 $\mu$ )	21.75	
	TPB	(0.01)	

TABLE X

One-gallon-mix properties of reduced-binder-energy formulation using AP, Al, and $\text{NaNO}_3$ solids.	
5	Tensile properties @ 2 in/min, 77°F
	$\sigma_n$ (psi) 244
	$\epsilon_n$ (%) 394
	$\epsilon_r$ (%) 394
10	$E_0$ (psi) 1570
	120°F viscosity (kP)
	$\eta_{0.36}$ 7
	$\eta_{0.008}$ 23
	120°F pot life (hr) >35
15	volume resistivity (ohm-cm) $1 \times 10^8$

This invention has been described herein in considerable detail in order to comply with the Patent Statutes and to provide those skilled in the art with the information needed to apply the novel principles and to construct and use embodiments as required. However, it is to be understood that the invention can be carried out by specifically different formulas and devices and that various modifications can be accomplished without departing from the scope of the invention itself.

25 What is claimed is:

# CLAIMS

1. An improved reduced energy binder for energetic compositions comprising an amount of at least one relatively high molecular weight cured polyester polyol polymer in combination with an amount of one or more energetic plasticizers.
2. The reduced energy binder of claim 1 wherein the ratio of plasticizer to polymer is less than 1.6:1.
3. The reduced energy binder of claim 2 wherein the polyester polymer is cured using an amount of a polyisocyanate.
4. The reduced energy binder of claim 1 wherein the polyester polymer is cured using an amount of a polyisocyanate.
5. The reduced energy binder of claim 2 wherein the polyester polyol is poly(tetramethylene adipate) having a molecular weight (MW) of at least 4,000.
6. The reduced energy binder of claim 3 wherein the polyester polyol is poly(tetramethylene adipate) having a molecular weight (MW) of at least 4,000.
7. The reduced energy binder of claim 5 wherein the PTMA has a MW of at least 6,000.
8. The reduced energy binder of claim 6 wherein the PTMA has a MW of at least 6,000.
9. The reduced energy binder of claim 2 wherein the energetic plasticizers are selected from nitrate esters of the group consisting of n-butyl-2-nitratoethyl nitramine; trimethylolethane trinitrate; triethyleneglycol dinitrate; butanetriol trinitrate; nitroglycerin and mixtures thereof.
10. The reduced energy binder of claim 5 wherein the energetic plasticizers are selected from nitrate esters of the group consisting of n-butyl-2-nitratoethyl nitramine; trimethylolethane trinitrate; triethyleneglycol dinitrate; butanetriol trinitrate; nitroglycerin and mixtures thereof.
11. The reduced energy binder of claim 9 wherein the plasticizer is selected from nitroglycerin, n-butyl-2-

nitratoethyl nitramine and trimethylolethane trinitrate.

12. The reduced energy binder of claim 10 wherein the plasticizer is selected from nitroglycerin, n-butyl-2-nitratoethyl nitramine and trimethylolethane trinitrate.

13. The reduced energy binder of claim 1 further comprising an amount of inert plasticizer.

14. The reduced energy binder of claim 13 wherein the inert plasticizer is triacetin.

15. An improved propellant composition comprising a binder that includes a high molecular weight polyester polyol binder polymer including poly(tetramethylene adipate) having a molecular weight above 4000 and an energetic plasticizer wherein the plasticizer to polymer ratio is less than about 1.6:1.

16. The propellant composition of claim 15 wherein the energetic nitrate ester plasticizer is selected from nitroglycerin, n-butyl-2-nitratoethyl nitramine and trimethylolethane trinitrate.

17. The propellant composition of claim 16 wherein the binder polymer has a molecular weight of about 6,000.

18. The propellant composition of claim 17 further comprising an amount of triacetin plasticizer.

19. The propellant of claim 17 wherein the plasticizer to polymer ratio is about 1:1.

20. An improved high solids propellant composition comprising by weight:

(a) about 11% poly(tetramethylene adipate) MW 6,000 binder polymer;

(b) about 12% nitroglycerin plasticizer;

(c) about 22% aluminum; and

(d) about 53% ammonium perchlorate.

21. The propellant composition of claim 20 wherein nitroglycerin fraction is replaced by about 12% trimethylolethane trinitrate.

22. The propellant composition of claim 20 wherein (d) comprises about 30% ammonium perchlorate and about 22% sodium nitrate.

23. An improved high solid propellant composition comprising by weight:

- (a) about 10% poly(tetramethylene adipate) MW 6000 binder polymer;
- 5 (b) about 11% nitroglycerin plasticizer;
- (c) about 2.5% triacetin plasticizer;
- (d) about 22% aluminum; and
- (e) about 53% ammonium perchlorate oxidizer.

24. An improved high solids propellant composition comprising by weight:

- 10 (a) about 7% poly(tetramethylene adipate) MW 6,000 binder polymer;
- (b) about 6.5% n-butyl-2-nitratoethyl nitramine;
- (c) about 1.4% triacetin;
- 15 (d) about 22% aluminum;
- (e) about 60% ammonium perchlorate; and
- (f) about 2% dicyandiamide.



REDUCED ENERGY BINDER FOR ENERGETIC COMPOSITIONS

ABSTRACT OF THE DISCLOSURE

Improved binders for energetic compositions include  
high molecular weight polyester polyol binder polymers and  
5 energetic plasticizers wherein the plasticizer to polymer  
ratio is 1.6:1 or less.

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**DECLARATION, POWER OF ATTORNEY, AND PETITION**

I, John R. Moser, Jr., a citizen of the United States of America, residing at 8496 Kings Cove Drive, Salt Lake City, Utah 84121, hereby declare that: my residence, post office address and citizenship are as stated above next to my name; and that I verily believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled "REDUCED ENERGY BINDER FOR ENERGETIC COMPOSITIONS", the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the specification including the claims as amended by any amendment specifically referred to in the Oath or Declaration.

I acknowledge the duty to disclose information which is material to patentability in accordance with Title 37, Code of Federal Regulations, Section 1.56.

I hereby appoint HAUGEN AND NIKOLAI, P.A., a professional association, consisting of the following attorneys/agents and the following attorneys/agents individually: Orrin M. Haugen, Registration No. 17,972, Thomas J. Nikolai, Registration No. 19,283, Charles G. Mersereau, Registration No. 26,205, Catherine C. Maresh, Registration No. 35,268, and Paul T. Dietz, Registration No. 38,858, of 820 International Centre, 900 Second Avenue South, Minneapolis, Minnesota 55402-3325; Telephone No. (612) 339-7461, my attorneys/agents with full power of substitution and revocation to prosecute this application and transact all business in the Patent

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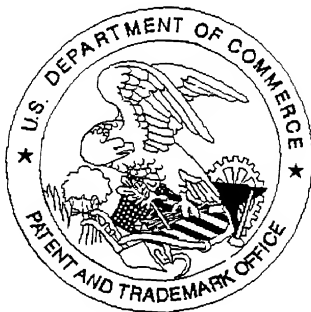
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